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A COMPLETE UNDERSTANDING OF NAVIGATION SYSTEM IN ORAL AND MAXILLOFACIAL SURGERY

Plastic Surgery

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ABSTRACT

Navigation system is one of the technologies which has completely transformed the management of any disease, disorder or condition in the field of surgery. Navigation surgery answers all the questions like, "Where is my anatomical target", "How to reach my target safely" or "where and how to position my implant while preserving vital structures". At present, application of the navigation system in the field of oral and maxillofacial surgeries are as following: localization of pathological changes or foreign objects, resections of tumour in close proximity to vital structures, orbit, maxillary sinus, surgical corrections of distinct maxillomandibular malformations and facial asymmetries in cases of disturbed craniofacial development, midfacial osteotomies or biopsy from the parapharyngeal space, in the placement of dental implants in anatomically complex sites such as pterygoid implants etc. Navigation system is also useful to perform safer and clean surgery in the other fields such as neurosurgery, knee replacement, hip replacement, cardiac interventions, coronary artery bypass grafting, intracardiac procedures etc. Navigation assisted surgery is a beneficial addition in the field of oral and maxillofacial surgery. There is no doubt that it provides reliability by increasing precision when planning any surgical resection or reconstruction. In addition, navigation surgery offers more security in operating complicated cases and may also provide a better clinical outcome if used judiciously. In this article, we present a review of the development of this rapidly evolving system, its components, principles and applications in the field of facial surgery.

KEYWORDS

Navigation Surgery, Oral and maxillofacial surgery, Plastic Surgery, Recent advancements in surgery.

INTRODUCTION:

Over the last few years, technology has become an intrinsic part of our everyday routine. Navigation system is one of the technologies which has completely transformed the management of any disease, disorder or condition in the field of surgery. Navigation surgery answers all the questions like, "Where is my anatomical target", "How to reach my target safely" or "where and how to position my implant while preserving vital structures".

Navigation system is a technical tool added in recent years in a surgeon's toolbox for a yearning desire to perform less invasive and safer surgery.

Understanding Navigation Surgery: In navigation assisted surgeries preoperatively obtained radiological three-dimensional (3D) scans are superimposed on the same patient's real anatomy in exact spatial relationship. This offers a surgeon 3D map of the patient's anatomy together with the site of any abnormalities. Intraoperatively surgical instruments are continuously tracked by the sensors of the navigation system and display monitors show the exact location of the instrument inside the patient's body.

Development of Navigation System:

The first experiment to exactly localize specific anatomical structures within the human body was done in the late nineteenth century [1]. Three important factors were responsible for the development of the navigation system in surgery: neurosurgery, stereotaxy and medical imaging [2]. Neurosurgery: brain lacks anatomical landmarks for orientation; therefore, neurosurgeons were the first adopters of this new technology [2]. Stereotaxy: Initially with the help of mechanical head frames (priorly setup) based on the anatomical drawing as on atlas for intracranial target planning transferred over actual intraoperative patient setup. It reduces the surgical risk of injuring any other vital structure and comparatively less invasive procedures [2]. It was E.A. Spiegel and H.T. Wycis who invented the first stereotactic instruments in 1950. Medical imaging: Medical imaging is a key prerequisite for navigation. The discovery of the X-ray in 1895 by Wilhelm Roentgen, the first computer tomography (CT) imaging device in 1970 by Sir Hounsfield and magnetic resonance imaging (MRI) in 1980 unlocked the way for a completely new era of medical diagnosis. In 1990 David Roberts invented the frameless stereotaxy machine which got the abilities to locate a surgical instrument in "real-time" and continuously visualize its position on the preoperative CT or MRI. This was the first model of the navigation system as we know it today [2].

Application of Navigation system: At present, application of the navigation system in the field of oral and maxillofacial surgeries are as following: localization of pathological changes or foreign objects, resections of tumour in close proximity to vital structures, the tumour of the skull base, parapharyngeal space, orbit, maxillary sinus, surgical corrections of distinct maxillomandibular malformations and facial asymmetries in cases of disturbed craniofacial development, surgical correction of enophthalmos, reconstruction of complex facial fractures like zygomaticomaxillary complex or nasoethmoidal fractures, midfacial osteotomies or biopsy from the parapharyngeal space, in the placement of dental implants in anatomically complex sites such as pterygoid implants etc [3-5].

Navigation system is also useful to perform safer and clean surgery in the other fields such as neurosurgery, knee replacement, hip replacement, cardiac interventions, coronary artery bypass grafting, intracardiac procedures etc.

Basic components of navigation System:

The necessary components to understand image-guided navigation system are: Tracking devices, Monitors, Trackable instrument, Skull reference array, Registration, Visualization and Software (Fig. 1).

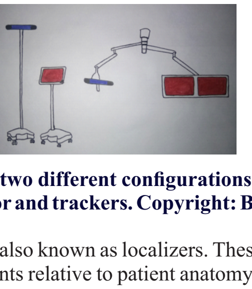

Fig. 1. The curve in two different configurations: ceiling mounted and portable monitor and trackers. Copyright: Brainlab AG

Tracking devices are also known as localizers. These devices track the positions of instruments relative to patient anatomy. There are various types of tracking systems used today. Most of them are (a) optical video metric system, (b) optical infrared trackers and (c) electromagnetic system [6].

Optical Videometric system uses one or more video cameras to identify markers on video image sequences. Optical infrared trackers are of three types, active, passive and combined. These trackers utilize light-emitting diodes (LEDs) operating in the infrared (IR) range as marker, tracked by using either two planer or three linear charge-coupled devices (CCD) cameras. The electromagnetic system is a recent development, this technology has enabled an extremely small sensor to be embedded in surgical instruments for tracking inside the body [6]. Optical tracking systems require that a line of sight be maintained between the tracking device and the instrument to be tracked, which is not always convenient and precludes the tracking of instruments inside the body. Due to this inconvenience, electromagnetic tracking systems were developed, which have no line-of-sight requirement and can track instruments such as catheters and the tips of needles inside the body [6]. A recent article comparing optical and electromagnetic tracking systems noted additional advantages of higher accuracy in optical tracking system [7].

Monitors: It is used for visualizing the virtual 3D image of the patient and surgical instrument during surgery.

Trackable instrument: There are various types of probe designs are available, however, the association between the infrared reflectors and the tip of the navigation probe is unbendingly defined. Navigation system tracks the tip of the instrument in space with around 1 mm precision [8].

Skull reference array: These are mainly the screw-retained parts. A skull post is applied to the cranium with a central fixation screw. The dynamic reference frame (DRF) is then attached to the skull post. Patient's 3D orientation in space is determined by this skull reference array. The tracking devices releases infrared light which is reflected off the skull reference arrays and instrument. The navigation system then triangulates the exact location of the reference arrays [8]. (Fig. 2)

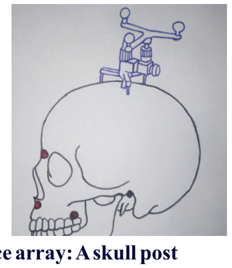

Fig. 2 Skull reference array: A skull post

Registration:
It is the process of alignment of the pre-operative images with the patient on the operative table. Markers are placed before taking radiographs and then preoperatively these markers are matched with preoperative images. There are several techniques used for patient registration.

A minimum of four fiducials are required on the virtual patient although the more markers are better.

The tip of the navigation probe is sequentially placed on each point. The navigation system uses these anatomical landmarks to triangulate the position of the physical patient in space relative to the DRF.

Independent of the registration strategy used, there are four basic principles for optimal fiducial placement. The greatest accuracy will be achieved by

- Using a maximal number of fiducial points.
- Separating the fiducials with the largest possible distance on the skull/skin.
- Placement of the surgical field at the centre of the fiducial markers.
- Not placing the fiducials in a single line or a single plane [8].

Fiducial markers can be a non-rigid or rigid fixation. Non-rigid is fixed on the skin with adhesives. Rigid can be of two types, bone markers and oral appliance. In bone fiducials, during registration probe is passed through the skin so it may be placed directly onto the bone surface. Bone fiducials may include anatomic landmarks (ie, suture lines or bone prominences etc.). If necessary, the surgeon may place bone screws in non-mobile segments of the skull or use previously placed hardware as fiducials for registration (Fig. 3).

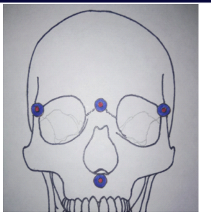

Fig. 3 Bone Markers

In dentate patients with a un-injured of the fixed maxilla, a dental splint containing fiducial markers can be fabricated to fit onto the patient's maxillary dentition (Fig. 4).

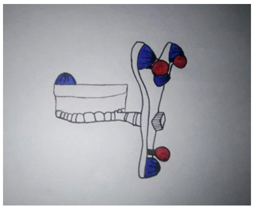

Fig. 4 Oral appliance: dental splint containing fiducial markers

It is necessary to obtain a CT scan with the splint and bone fiducials in place [8].

Software: It is a critical constituent of image-guided surgical navigation. The software must integrate information from tracking systems, correlate the data with the relevant images and display real-time updates of the instruments and patient [6].

Steps of Image-guided surgical intervention:
The steps required for image-guided interventions using computer assistance are:

1). Acquire pre-operative tomographic images,
2). Register patient's anatomy to the pre-operative image,
3). Surgical instruments are tracked using a localizer,
4). Position of the surgical instruments is displayed on the monitored image relative to the patient anatomy,
5). The surgeon uses this virtual display to manipulate the instruments to accomplish the procedure.

Currently available systems: A wide variety of navigation platforms are available to accommodate all surgical needs [4]. Some of the system based on optical tracking are: Viewing Wand this was the first frameless neuro-navigation device, Columbia scientific Simplant software, VISIT surgical navigation software, Vector Vision, Stryker Leibinger Navigation System, projector-based systems: Surgical Microscope Navigation System, Surgical Segment Navigator, Microscope-Assisted Guided Interventions (MAGI). Recently developed based on an electromagnetic system: Head-mounted display system, Insta Trak (GE medical systems) [6].

DISCUSSION:
The benefits of navigation surgery have been reported in a number of studies. The integration of imaging with the surgical field allows visualization of different type of images simultaneously, show structures that are normally only visible intra-operatively, and permit intra-operative navigation in areas of anatomical sensitivity. Hongbo Yu in 2013 operated 104 patients including 34 zygomatic-orbital-maxillary fractures, 27 unilateral TMJ ankylosis, 29 craniofacial fibrous dysplasia, 9 mandibular angle hypertrophia, 3 cartilage bone tumours of jaw and 2 cases with facial foreign bodies successfully using intraoperative navigation; none of the patients developed any intraoperative or postoperative complication. The navigation system error measured by computer was reported less than 1 mm after registration. The mean deviation between the preoperative design and actual surgical results was 1.46 + 0.24 mm [9].

Annette M. Pham in 2007 reported navigation allowed accurate repositioning of the zygomaticomaxillary complex to within approximately 2 mm of the contralateral side and allowed accurate positioning of the mobilized frontal bone segments, resulting in improved facial symmetry [10]. Gunkel et al tested five different navigation systems for preoperative planning and intraoperative navigation in the paranasal sinuses, frontal and lateral skull base, and

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petrous bone, and reported an accuracy of 1 to 2 mm [11]. Makoto Ieguchi in 2011 performed navigation assisted surgery in 9 benign bone tumours and 7 malignant bone and soft tissue tumours. According to the author the mean accuracy of the system, which was determined using skin markers, was 0.93 mm (range, 0.6–1.2 mm) [12]. Stefan Hassfeld used 3-D navigation systems for surgeries of the skull base. According to him, navigation systems are very helpful in identifying the extent of the tumours, thus increasing the extent of radical resection especially within the labyrinth of the paranasal sinuses, and in visualizing the proximity of vital structures, e.g. the carotid arteries, brain stem or cranial nerves. He also reported accuracy of the systems to be very high in skull base surgery, with a deviation of < 2.7 mm on average, based on CT-data [13]. Elijah Zhengyang Cai in 2012 operated 29 patients with orbital fractures using the navigation system. He concluded the use of navigation in orbital reconstructive surgery improves surgical outcomes by minimizing postoperative complications, thereby reducing the need for a second operation [14].

Conclusion: Navigation assisted surgery is a beneficial addition in the field of oral and maxillofacial surgery. There is no doubt that it provides reliability by increasing precision when planning any surgical resection or reconstruction. In addition, navigation surgery offers more security in operating complicated cases and may also provide a better clinical outcome if used judiciously. However, the cost-effectiveness and increased operating time still stand as disadvantages of this system and further research is needed in this direction.

DISCLOSURES:

CONFLICT OF INTEREST- None.

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We agree if this manuscript is accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder.

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